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DEVICE FOR COOLING AN ELECTRICAL APPLIANCE

The invention relates to a cooling device for an electric machine according to the preamble of claim 1.

Cooling devices in electric machines, such as computer systems, must be designed such that adequate cooling is achieved with little noise emission. At the same time, system safety must be increased and the costs lowered.

Intel, Microsoft and Toshiba have published an ACPI specification that describes some fundamental approaches to solving this problem. ACPI stands for "Advanced Configuration and Power Interface". It is an interface specification for the exchange of information between the hardware of a PC, the associated operating system and the associated peripheral devices. The specification defines a format in which operating system, motherboard hardware and peripheral devices, such as CD ROM drive, hard disk, etc. are able mutually to exchange data on energy consumption. The main goal of ACPI is to ensure Operating System Directed Power Management (OSPM), in which the operating system has access to all power management functions and thus can match the energy consumption of the individual devices precisely to the respective need (see Internet address http://www.andygrove.com/deutsch/mobile/mobilePCs/acpimen.htm).

One problem of the ACPI specification is that, as illustrated in Fig. 1, it relates to individual thermally closed zones, each comprising a sensor and an associated cooling method, which in turn can comprise several units (such as fans). The control loop of a cooling method comprises the actuator for cooling (such as fan or CPU clock reduction/modulation), the actual-value sensor (temperature sensor), the perturbing variable (such as power loss of the CPU) and the controller. In ACPI, the controller, as a component of the operating system, is configured in software on

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the CPU of the computer system. This requires that the computer system be fully functional, and means in turn that the cooling control loop is intact only as long as the cooling system is functioning.

In the example of Fig. 1, implemented according to ACPI, the system comprises three mutually independent zones. A further problem in this connection is that thermal interactions between the zones are not sensed. This in turn means that no allowance can be made for them.

The object of the present invention is to provide an improved cooling device for an electric machine, which ensures adequate cooling with little noise emission and thus creates the possibility that cooling means can be made smaller or completely eliminated, that universal adaptation to various machine configurations is feasible, or that the cooling loop remains functional even if the system to be cooled has failed. A further object is to provide a temperature-control unit for such a cooling device.

This object is achieved by a cooling device having the features of claim 1.

The inventive cooling device advantageously exploits the circumstance that interactions exist between the individual thermal zones. By virtue of the interactions, the cooling method for one thermal zone exerts an influence on another thermal zone. This situation is advantageously exploited to the effect that the cooling means of the one thermal zone support the cooling means of the other thermal zone. It may then even be possible to dispense completely with cooling means. To ensure that this advantage is obtained, thermal zones interacting with one another are combined as one uniform thermal zone, whereby the individual cooling means provided therein can supplement or replace one another. Such a cooling device has the further advantage that it is the basis for further advantageous embodiments.

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Further advantageous embodiments of the invention are specified
in the dependent claims.

As examples according to those claims, maximum-value generators
and/or at least one allocation matrix are used.

Maximum-value generators make it possible to determine a
manipulated variable on the basis of information from a plurality
of controlling elements, of which that which indicates the most
critical case is ultimately used for control. In this way it is
ensured that the most critical temperature always dictates which
variable will be manipulated.

On the one hand, the allocation matrix permits flexible
allocation of more than one controlling element (for CPU and
system temperature, for example) per actuator (fan, for example).
On the other hand, the allocation matrix also permits flexible
allocation of one controlling element to a plurality of
actuators.

The combination of a flexible allocation matrix with maximum-
value generators permits universal interconnection of controlling
elements and actuators present in a system, such that the
proposed cooling device can be used with the above advantages for
all system configurations.

An embodiment of the invention according to claim 6 has the
advantage that control of the cooling functions is also
completely operable even if the operating system or the CPU and
the associated components such as chipset, memory, etc. of a
computer system, considered as an example of an electric machine,
are malfunctioning. Thus an increase in reliability of an
affected system is achieved with the invention. Furthermore, the
cooling function is assured even if the operating system does not
support any power management functions such as ACPI.

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The basis of the advantageous embodiment is that the control
systems are decoupled from the thermal zones to be monitored. It
is no longer the unit to be cooled, such as the CPU of a computer
system and its components, that is responsible for monitoring and
control of cooling, but instead monitoring and control of cooling
take place independently of the system to be cooled.

If functions for monitoring and cooling control are implemented
in an independent unit, cooling devices which originally were not
designed with a cooling device according to one of claims 1 to 5
can be operated according to the principle of this cooling
device. Moreover, ASICs or microcontrollers can be used cost-
effectively for such units. Such ASICs or microcontrollers, for
example, do not have to be designed exclusively for monitoring
and cooling control.

Further explanations will be provided and two practical examples
of the invention will be described in more detail hereinafter
with reference to a drawing, wherein, individually,

Fig. 1   shows a system structure of an electric machine
          subdivided into thermal zones, according to the prior
          art,
Fig. 2   shows a system structure of an electric machine
          subdivided into thermal zones, wherein the thermal
          zones overlap, according to the prior art,
Fig. 3   shows a system structure of an electric machine
          subdivided into thermal zones, one of the thermal zones
          being enclosed, according to the prior art,
Fig. 4   shows in principle the system structure according to
          the invention,
Fig. 5   shows a first practical example according to the
          invention, and

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Fig. 6   shows a second practical example according to the
           invention.

Fig. 2 shows an example of overlapping thermal zones. Fig. 3
shows an example of enclosed thermal zones.

Overlapping or enclosed thermal zones such as illustrated in
principle in Figs. 2 and 3 are found frequently in practice. In
these cases, thermal interactions take place between the
individual thermal zones.

Fig. 4 shows a schematic diagram of an inventive cooling device
for a single actuator. In contrast to other principles (such as
ACPI), allowance for thermal interaction between the different
thermal zones can be made with such a cooling device. For this
purpose all thermal zones with interactions are reduced to one
thermal zone in which all temperature sensors (actual-value
sensors) and cooling methods (actuators) are enclosed. Allowance
for the interaction is achieved since, in a cooling device
according to Fig. 4, not only one single controlling element but
also a plurality of controlling elements can influence a
actuator. For this purpose the embodiment provides a flexible
allocation matrix for the controlling elements and a maximum-
value generator to generate maximum values for each actuator. In
this way the practical requirements of overlapping or enclosed
thermal zones are taken into account.

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This has the advantageous effect that the number of necessary fans can often be decreased, thus lowering costs and reducing noise emission.

A further advantage is that, in systems with several cooling methods, the expense for each individual cooling method can be reduced by allowing for the interactions. An example of several cooling methods is a system with an "enclosed thermal zone". Such a system is, for example, a CPU with attached fan in a PC cabinet containing a power supply with integrated fan. Instead of designing the cooling method corresponding to the enclosed zone (CPU fan) for the worst case (minimal air flow in the system), an excessive rise of CPU temperature is also countered by increasing the speed of the fan in the power supply. Thereby the temperature in the electric machine is lowered and the flow velocity is increased even in the region of the CPU, thus improving cooling of the CPU. Here also the costs and the noise emission can be reduced by appropriate choice of parameters.

Fig. 5 shows a practical example in which cooling of a PC system is achieved with only one fan and 3 sensors. In this example, the flexible allocation matrix is used only for connecting the three controlling elements to the maximum-value generator for the "system fan" actuator. The three thermal zones (CPU, hard disk and system) have an interaction. The system fan functioning as actuator acts on all thermal zones. This arrangement is therefore combined as one "entire system" thermal zone, and the fan speed is dictated by generation of a maximum value from the three controller output variables. In other words, the most critical temperature dictates the fan speed. Minimization of the costs and of the fan noise is achieved by the reduction to only one fan in the system.

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Fig. 6 shows a practical example relating to cooling of a system
in which the CPU is a thermal "hot spot" with its own fan. In
such a typical computer system, it may be practical to provide an
additional cooling method (fan, clock reduction, ...) for the CPU
"hot spot", since the system fan or the fan in the power supply
indeed has an influence on the CPU temperature, but is spatially
too far away, or the air stream cannot be directed selectively
onto the CPU.

In this example the combination of CPU and CPU fan is an enclosed
thermal zone, which has an interaction with the surrounding
"entire system" thermal zone.

The control loop for the "CPU fan" actuator is a classical
controller such as can also be implemented with ACPI. Since in
this case only the "CPU temperature" controller influences the
"CPU fan" actuator, no maximum-value generation would be
necessary for this actuator. Nevertheless, this universal
arrangement makes it possible at any time to connect the
influence of a further controlling element to the actuator by
means of the flexible allocation matrix.

The three thermal zones (CPU, hard disk and system) have an
interaction. The system fan functioning as actuator acts on all
three thermal zones. This arrangement is therefore combined as an
"entire system" thermal zone, and the fan speed is dictated by
generation of a maximum from the three controller output
variables. As in the foregoing example, this maximum generation
ensures that the speed of the system fan corresponds to the most
critical temperature. The flexible allocation matrix in this case
ensures that the "CPU temperature" controlling element influences
both actuators (CPU and system fans).

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Since both cooling methods have an influence on the CPU temperature, it is ensured hereby that the cooling method for the enclosed zone is selectively unburdened by the cooling method of the surrounding zone. Instead of designing the cooling method corresponding to the enclosed zone (CPU fan) for the worst case (minimal air flow in the system, or maximum internal temperature of the system), an excessive rise of CPU temperature is also countered by increasing the speed of the system fan. In this situation the CPU fan can be designed for lighter duty by appropriate choice of the control parameters. In turn, the costs and the noise emission are reduced hereby.